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GB 1498429
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(54) Electric power generating plant with energy storage

(57) Coal gasification produces a low BTU gas which, after purification, is divided into two parts, one part being passed direct to a combustion zone for the generation of electric power via a gas turbine or steam power plant. Another part of this low BTU gas is passed to a reactor where methanol is formed. The methanol is easily stored in its liquid form (as an energy store) and later may be used directly in the gas turbine for production of peak-load electricity or for export to fuel other facilities.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1.

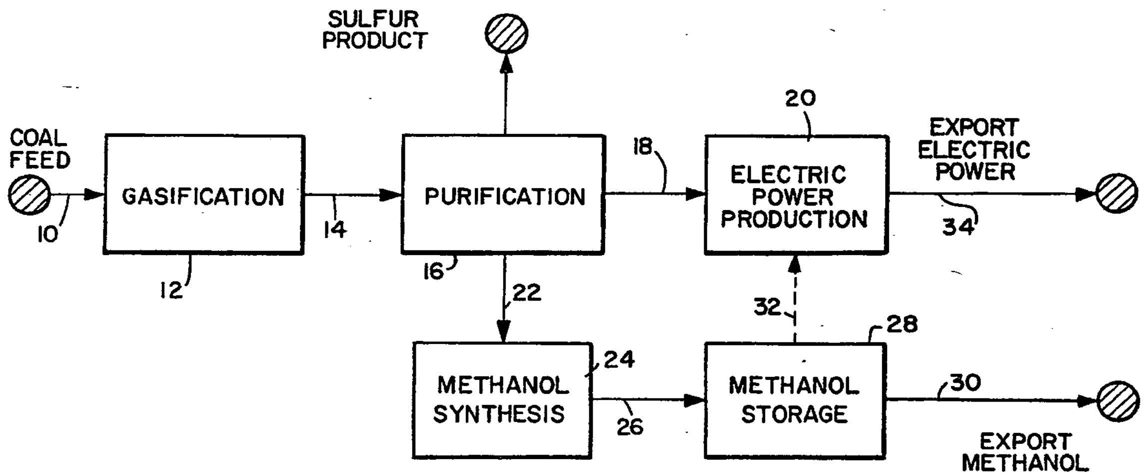

SULFUR PRODUCT
COAL FEED
GASIFICATION
PURIFICATION
ELECTRIC POWER PRODUCTION
EXPORT ELECTRIC POWER
METHANOL SYNTHESIS
METHANOL STORAGE
EXPORT METHANOL
10
12
14
16
18
20
22
24
26
28
30
32
34

FIG. 2.

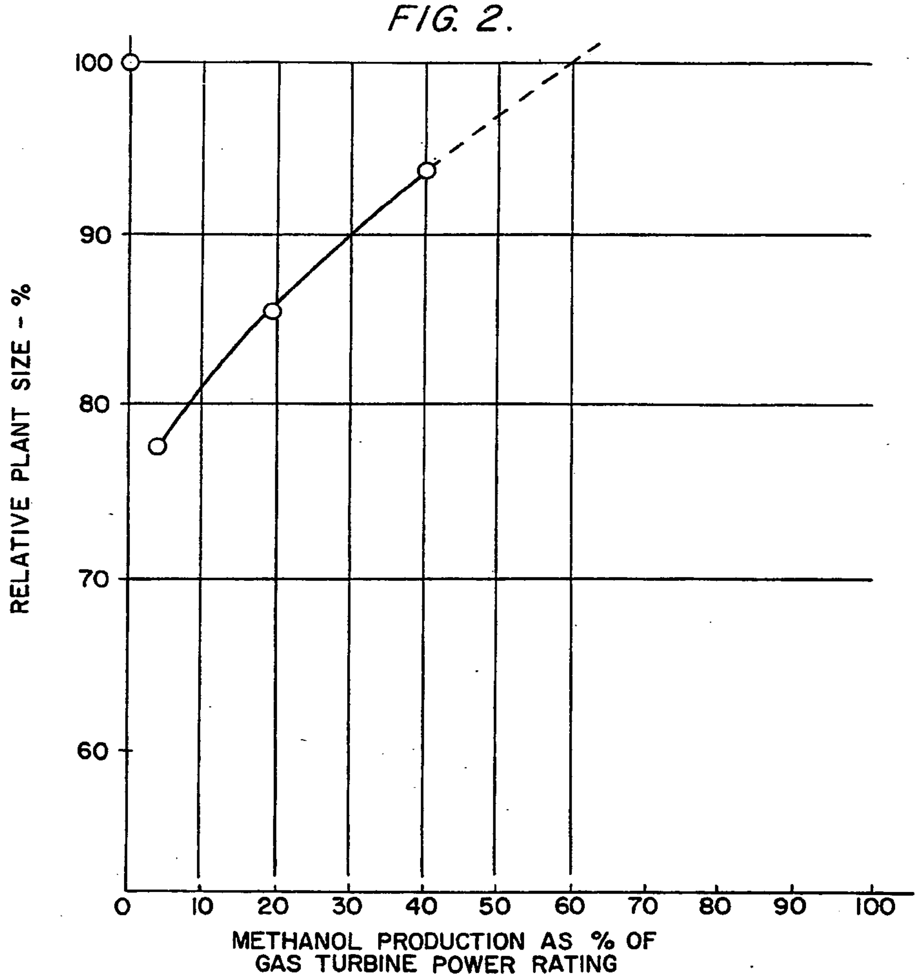

RELATIVE PLANT SIZE - %
100
90
80
70
60
0
10
20
30
40
50
60
70
80
90
100
METHANOL PRODUCTION AS % OF GAS TURBINE POWER RATING

FIG. 3.

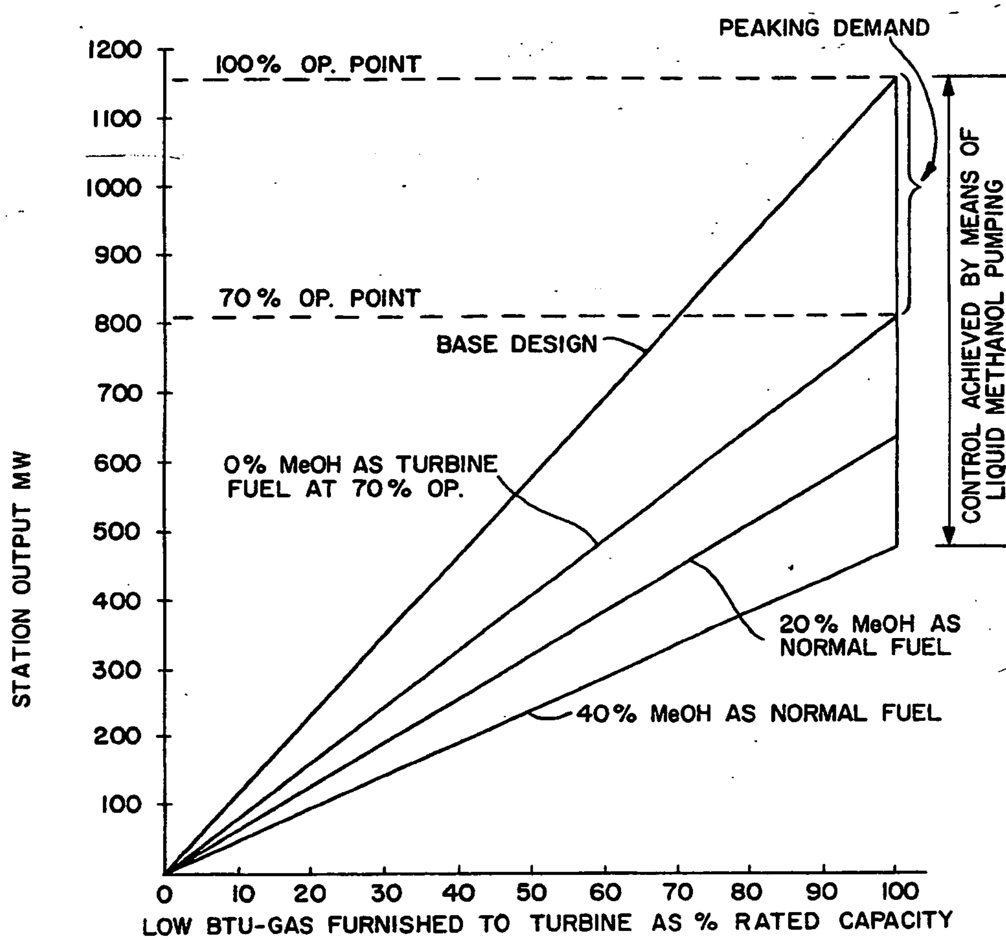

PEAKING DEMAND
100% OP. POINT
70% OP. POINT
BASE DESIGN
0% MeOH AS TURBINE FUEL AT 70% OP.
20% MeOH AS NORMAL FUEL
40% MeOH AS NORMAL FUEL
CONTROL ACHIEVED BY MEANS OF LIQUID METHANOL PUMPING
STATION OUTPUT MW
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
LOW BTU-GAS FURNISHED TO TURBINE AS % RATED CAPACITY

FIG. 4.

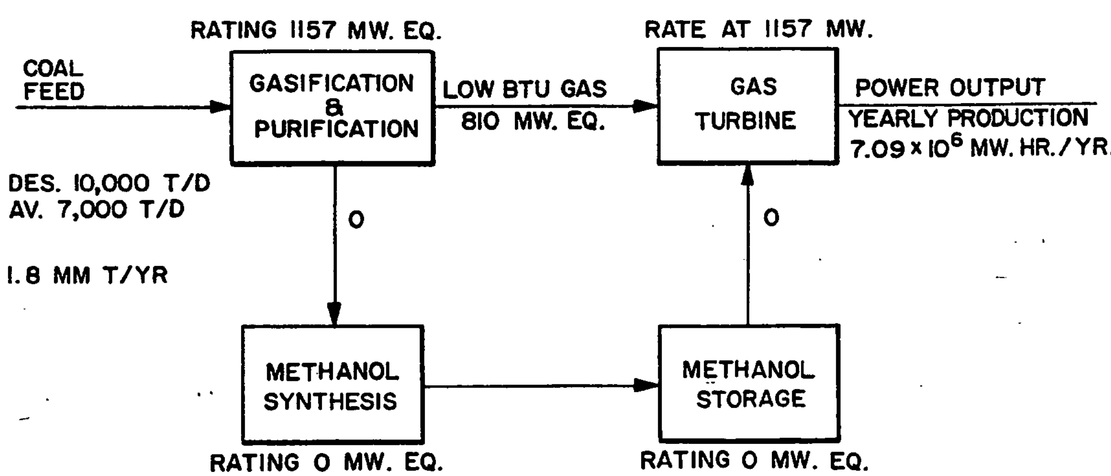

RATING 1157 MW. EQ.
RATE AT 1157 MW.
COAL FEED
GASIFICATION & PURIFICATION
LOW BTU GAS 810 MW. EQ.
GAS TURBINE
POWER OUTPUT
YEARLY PRODUCTION 7.09 x 10^6 MW. HR./YR.
DES. 10,000 T/D
AV. 7,000 T/D
1.8 MM T/YR
0
0
METHANOL SYNTHESIS
METHANOL STORAGE
RATING 0 MW. EQ.
RATING 0 MW. EQ.

FIG. 5.

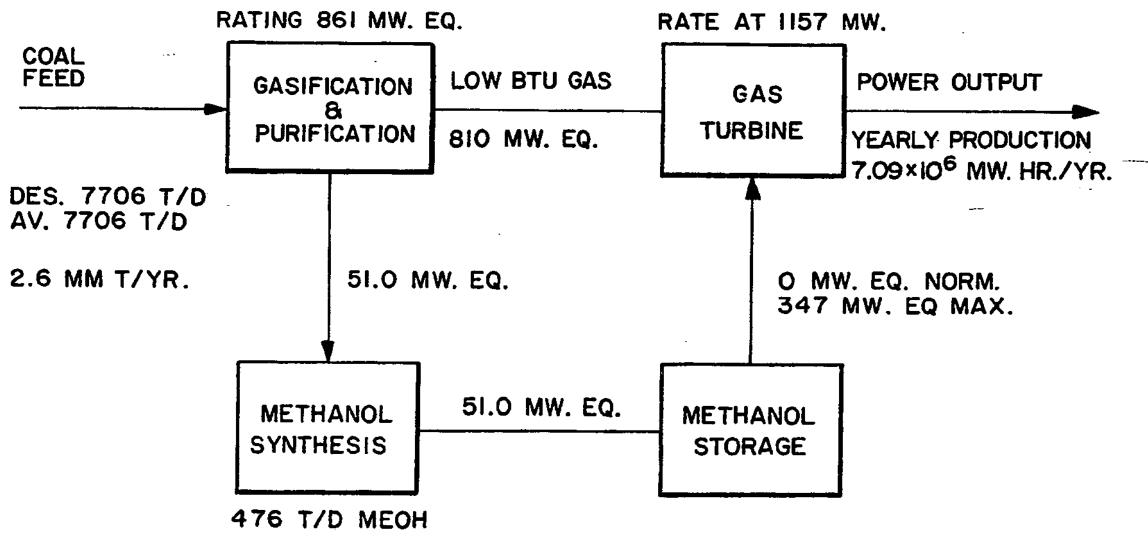

RATING 861 MW. EQ.
RATE AT 1157 MW.
COAL FEED
GASIFICATION & PURIFICATION
LOW BTU GAS
810 MW. EQ.
GAS TURBINE
POWER OUTPUT
YEARLY PRODUCTION
7.09×10⁶ MW. HR./YR.
DES. 7706 T/D
AV. 7706 T/D
2.6 MM T/YR.
51.0 MW. EQ.
0 MW. EQ. NORM.
347 MW. EQ MAX.
METHANOL SYNTHESIS
51.0 MW. EQ.
METHANOL STORAGE
476 T/D MEOH

FIG. 6.

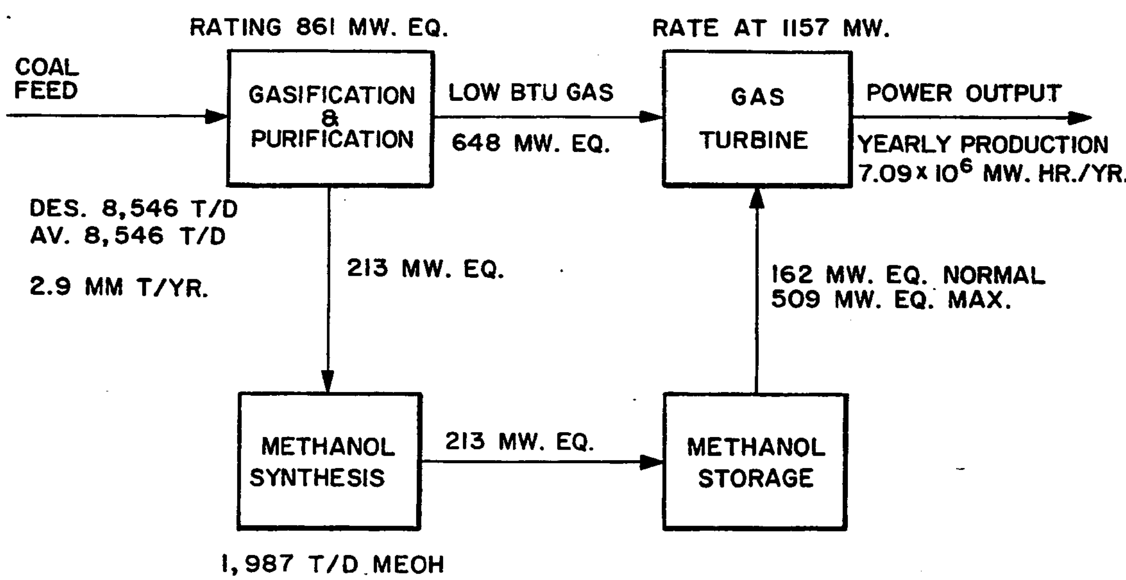

RATING 861 MW. EQ.
RATE AT 1157 MW.
COAL FEED
GASIFICATION & PURIFICATION
LOW BTU GAS
648 MW. EQ.
GAS TURBINE
POWER OUTPUT
YEARLY PRODUCTION
7.09×10⁶ MW. HR./YR.
DES. 8,546 T/D
AV. 8,546 T/D
2.9 MM T/YR.
213 MW. EQ.
162 MW. EQ. NORMAL
509 MW. EQ. MAX.
METHANOL SYNTHESIS
213 MW. EQ.
METHANOL STORAGE
1,987 T/D MEOH

FIG. 7.

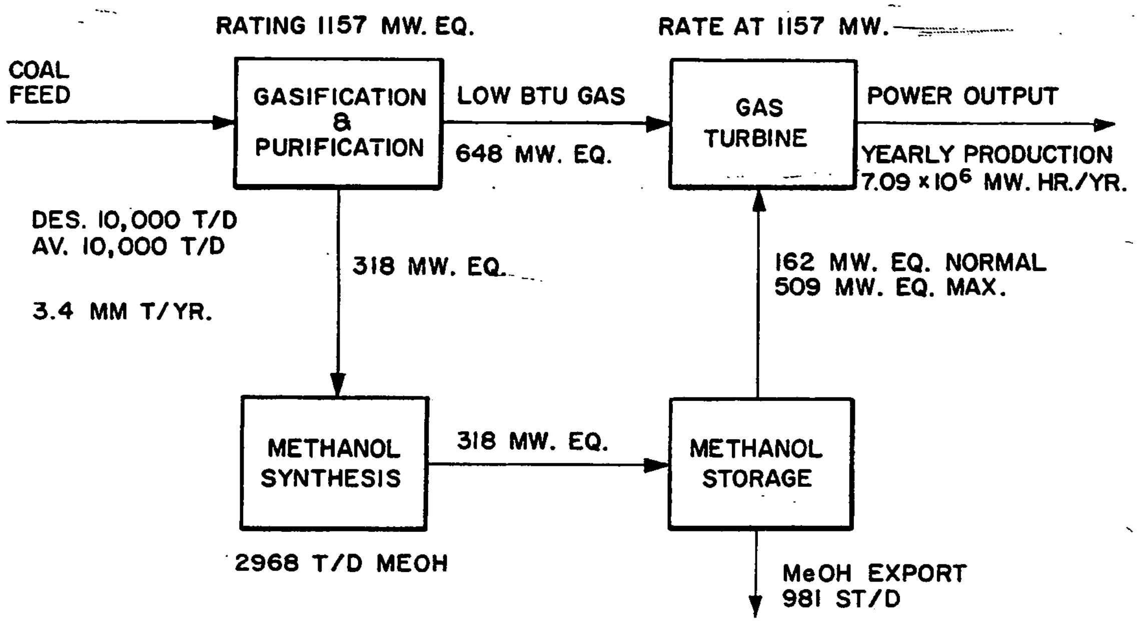
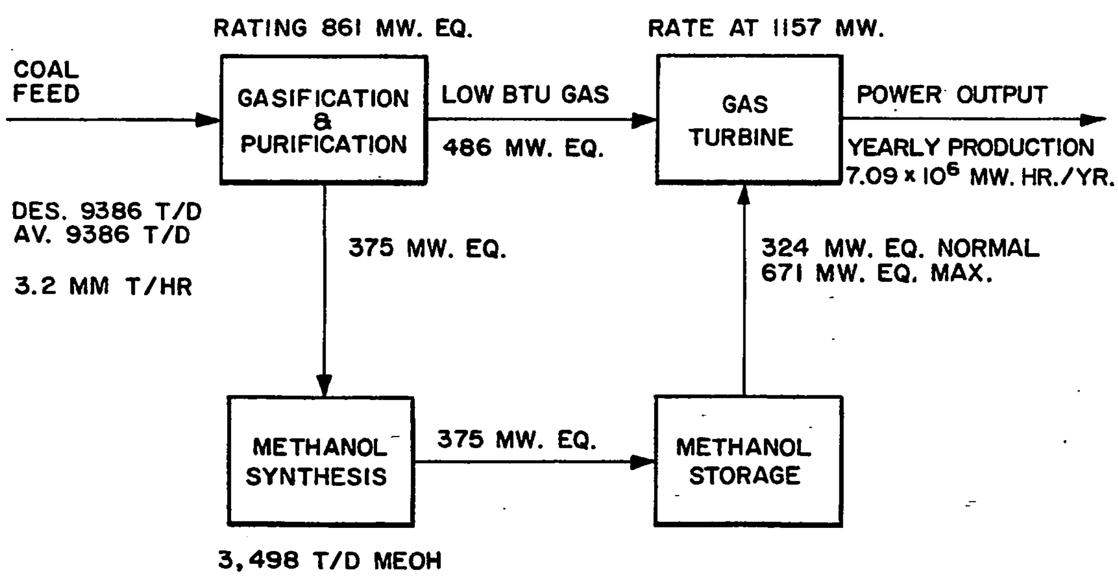

RATING 1157 MW. EQ.
RATE AT 1157 MW.
COAL FEED
GASIFICATION & PURIFICATION
LOW BTU GAS
648 MW. EQ.
GAS TURBINE
POWER OUTPUT
YEARLY PRODUCTION 7.09 x 10^6 MW. HR./YR.
DES. 10,000 T/D
AV. 10,000 T/D
3.4 MM T/YR.
318 MW. EQ.
162 MW. EQ. NORMAL
509 MW. EQ. MAX.
METHANOL SYNTHESIS
318 MW. EQ.
METHANOL STORAGE
2968 T/D MEOH
MeOH EXPORT
981 ST/D

FIG. 8.


RATING 861 MW. EQ.
RATE AT 1157 MW.
COAL FEED
GASIFICATION & PURIFICATION
LOW BTU GAS
486 MW. EQ.
GAS TURBINE
POWER OUTPUT
YEARLY PRODUCTION 7.09 x 10^6 MW. HR./YR.
DES. 9386 T/D
AV. 9386 T/D
3.2 MM T/HR
375 MW. EQ.
324 MW. EQ. NORMAL
671 MW. EQ. MAX.
METHANOL SYNTHESIS
375 MW. EQ.
METHANOL STORAGE
3,498 T/D MEOH

SPECIFICATION

Process for the production of electric power

Electric power generation plants operate under varying load conditions. Large scale base loaded plants may operate about 6,500 hours/year. Supplemental power generation is required to meet the total system demand and this added production is usually met with either mid-range plants which operate about 5,000 hours/year or peaking plants which may operate up to about 2,000 hours/year. Generally base loaded plants are designed for minimum fuel consumption and optimum efficiency. The peaking plants, which operate for relatively few hours per year, are generally designed for minimum capital cost and can tolerate a somewhat more expensive fuel than can the base load plant.

Conventional fuels for electric power generation have become expensive, scarce and in some cases environmentally unacceptable. An attractive alternate is the gasification of coal to produce a clean low BTU gas which is then combusted in a gas turbine. A number of studies have shown that this particular general processing scheme may be the most economical way to produce electric power in the future. The plants to produce low BTU gas are essentially process plants. This type of plant is normally designed for an on-stream availability of about 95%, i.e., roughly 8,280 hours/year. A base load electric powerplant normally operates at about 74.2% on-stream availability. It would be desirable to design a plant in such a way as to be able to operate the low BTU gas production facility at an availability which is as high as possible. Utilization of the maximum capacity of the plant requires some form of energy storage.

A number of different means of energy storage have been considered and utilized in the past. Pumped water storage is one means. Another means is compressed air storage.

The present invention involved the production of methanol from the excess gas from a coal gasification process. The methanol, being a liquid, is readily stored to provide the advantage of either using it in the gas turbine or exporting it to other facilities.

Advantages of methanol other than the fact that it is liquid and easily stored include its capability of being supplied to a turbine on demand and the expectation that it can be fed to a turbine burning low BTU gas as a supplemental fuel. Further, methanol contains no sulfur and burns cleanly. Excess methanol can be shipped away to fuel existing boilers operated by the power company synthesizing it or alternatively, it can be marketed to other users as a clean fuel for an appropriate application.

The present invention also contemplates the large scale production of methanol for use as a fuel with a small quantity of gas being withdrawn for electric power. Methanol can be used either as a gasoline supplement (to produce gasohol) or alternatively can be processed in a conversion process to produce gasoline directly from the methanol. The total methanol production will vary as a function of the amount of low BTU gas supplied to the power generation facilities on demand; the more gas supplied for power generation, the less available for synthesizing methanol.

FIG. 1 is a schematic flow diagram illustrating the broad concept of the present invention;

FIG. 2 is a graph showing methanol production as a percentage of the gas turbine power rating versus the relative plant size percentage;

FIG. 3 is a graph of the gas furnished to the turbine as a function of electrical output;

FIG. 4 is a schematic flow diagram of one embodiment of the present invention;

FIG. 5 is a schematic diagram of a second embodiment of the present invention;

FIG. 6 is a schematic diagram of a third embodiment of the present invention;

FIG. 7 is a schematic diagram of a fourth embodiment of the present invention; and

FIG. 8 is a schematic diagram of a fifth embodiment of the present invention.

FIG. 1 schematically illustrates the invention. Coal is fed through a line 10 to a gasification zone 12 where the coal is gasified. The gasification process practiced within the gasification zone 12 may be any practicable process such as ~~the~~ U-GAS process.

The product of the gasification process is an impure low BTU gas which is flowed through a line 14 to a purification zone 16 where a purification process such as the Selexol process or the Rectisol process removes sulfur. Removal of sulfur at this stage obviates its removal from the exhaust gas of a downstream combustion reaction. Desulfurization of flue gas is a comparatively expensive and difficult procedure. It is possible to remove carbon dioxide from the gas in the purification process to permit the downstream methanol synthesis reaction to proceed without the yield of water. The basic reaction produces methanol from hydrogen and carbon monoxide present in the low BTU gas as follows:

$$2H_2 + CO \rightarrow CH_3OH.$$

With carbon dioxide present, a portion of the hydrogen in the low BTU gas would react with the carbon dioxide as follows:

$$3H_2 + CO_2 \rightarrow CH_3OH + H_2O.$$

The latter reaction is desirable where the methanol is to be used as a fuel in a gas turbine. The water vapor in the fuel provides a comparatively high mass flow and a concomitant enhanced energy transfer to the turbine blades. However, for economic reasons the present invention does not contemplate a separate purification zone to prepare the gas for specific use in methanol synthesis to yield a water content, therefore, it is generally desirable to remove carbon dioxide as well as elemental sulfur

in the purification process.

After purification, the purified low BTU gas flows through two lines, or either of them, depending on its ultimate use. It can be fed through a line 18 to an electric power production process 20 or it can be flowed through a line 22 to a methanol synthesis process 24 or both.

The electric power production may be one where the gas is combusted to drive a gas turbine or one where it is combusted to release heat for the generation of steam or any other suitable electricity generating process.

In the present invention, the electric power production process would most likely be one where a gas turbine was employed. This is so because it is at present thought that the invention would have greatest applicability as a mid-range or peak-load plant where gas turbines are at present preferred by many plant operators.

The gas which flows through line 22 to the methanol synthesis procss is there used to synthesize methanol. The particular process used may be the ICI process or any other appropriate process. The methanol flows through line 26 to methanol storage 28 where it is retained until it is exported (dotted line 30) or alternately fed through a line 32 to the electric power production process 20 as a supplemental fuel to aid in the generation of electric power. The electric power produced is transmitted through the line 34.

FIG. 2 is a graphic representation of the relative plant size versus the methanol production as a percentage of gas turbine power rating. These quantitative terms require some explanation. The relative plant size, given as a percentage, is actually the input of gas through line 18 which fuels electric power production at the given percentage of the rated output of the electric power production equipment. Thus, where a gas turbine takes gas in the amount necessary to drive the power producer at 80% of its rated capacity through line 18, the amount of methanol produced represents approximately 8% of the gas turbine power rating. Similarly, when the gasification process 12 and purification process 16 provide, through line 18, low BTU gas at a rate sufficient to drive the gas turbine at 86% load, methanol production is that which would account for approximately 20% of the gas turbine power rating and methanol production will be the equivalent of 40% of the gas turbine power rating when the gas from line 18 is to drive the turbine at approximately 94% of rated capacity.

FIG. 3 is a graph showing the relationship between station output in megawatts (MW) against turbine intake of low BTU gas expressed as percentage of rated capacity of turbine output.

Again, the percentage along the abscissa represents the amount of gas (volume or weight per unit time) required to drive the turbine to produce power at the indicated percentage of the rated capacity of the power plant. Thus, when low BTU gas is fed to the gas turbine in the amount to be equal to 810 MW and the gas turbine is rated at 1157 MW, that is, where the low BTU gas is fed to the turbine at a rate sufficient to operate it at 70% capacity, in order to bring the turbine up to rated capacity, methanol must be supplied at a rate where the equivalent of 347 MW is made available at the turbine to augment the pure low BTU gas. The graph for 10 the base design indicates the relationship of the quantities when the gasifier can supply 100% of the low BTU gas required to run such a turbine at rated capacity. Another line shows this relationship when the fuel is a mixture of low BTU gas and methanol, the mixture being 20% by weight of methanol. Still another line represents the relationship when the fuel is 40% by weight of methanol and 60% low BTU gas.

FIGS. 4 through 8 are schematic drawings of alternate embodiments and have no reference numerals. In view of the illustration of the invention in FIG. 1, the explanation above and the explanatory labeling on FIGS. 4 through 8, omission of the reference numerals makes the description of those figures more scrutable.

FIG. 4 shows an embodiment where the gasification and purification processes can handle 10,000 tons per day of coal and are operated to consume, on the average, 7,000 tons per day. The gasification and purification processes which are capable of furnishing 1157 MW (megawatts) equivalents of low BTU gas is operated so as to furnish 810 MW equivalents. A gas turbine rated at 1157 MW produces 7.09×10^6 MW hours per year. In this embodiment, no gas is fed to methanol synthesis and, of course, no methanol is produced.

A second embodiment illustrated schematically in FIG. 5 is one where a gasification and purification process designed to handle 7,706 tons per day of coal operates at that rate to provide 810 MW equivalents of low BTU gas to the turbine. Fifty-one megawatt equivalents of gas are fed to methanol synthesis where 476 tons per day of methanol are produced. This production which represents 51 MW equivalents is led to methanol storage so that methanol may be furnished to the gas turbine at a flow rate any where between 347 MW equivalents and zero.

FIG. 6 represents a third embodiment where the gasification and purification processes are capable of handling 8,546 tons per day and are operated at full capacity. Low BTU gas in the amount of 648 MW equivalents is furnished to a gas turbine which is rated at 1157 MW as is the gas turbine in the embodiments of FIGS. 4 and 5. Two hundred thirteen megawatt equivalents of the gas is fed to the methanol synthesis process to result in the synthesis of 213 MW equivalents of methanol which is fed to storage. In this embodiment (FIG. 6), the gasification and purification processes have a rating of 861 MW equivalents. The same amount of low BTU gas can be synthesized but less is furnished to the turbine, a larger flow being directed to the methanol synthesis process. Specifically, methanol can be fed to the gas turbine at a normal feed rate of 162 MW equivalents and a maximum of 509 MW

equivalents.

The capacity of gasification and purification processes as well as the capacity of the turbine in the embodiment of FIG. 6 are the same as in the embodiment of FIG. 5. However, in the embodiment of FIG. 6 more of the low BTU gas is converted into methanol and of course, more is available as fuel for the gas turbine.

In the embodiment of FIG. 7 the capacity of the gas turbine is the same as in the embodiments of FIGS. 4, 5 and 6. FIG. 7, however, shows gasification and purification combined processes which can provide more low BTU gas than the embodiments of FIG. 5 or FIG. 6 and as much as the embodiment of FIG. 4. In this embodiment 648 MW equivalents are fed to the gas turbine while 318 MW equivalents are directed to methanol synthesis and then to methanol storage and at a normal rate of 162 MW equivalents methanol can be fed to the gas turbine. The maximum flow of 509 MW equivalents of alcohol can be directed from methanol storage to the turbine and methanol at the rate of 981 short tons per day can be exported.

In the embodiment of FIG. 8 the gas turbine is the same capacity as that of FIG. 7, whereas the gasification and purification processes are capable of furnishing 861 MW equivalents of low BTU gas, the same as the gasification and purification processes of FIGS. 5 and 6 where 486 MW equivalents of low BTU gas are directed to the gas turbine. In the FIG. 8 embodiment 375 MW equivalents are fed to the methanol synthesis process to result in the synthesis of methanol in the amount of 375 MW equivalents. The methanol is led to storage so that there is sufficient methanol available at all times to feed the turbine at a normal rate of 324 MW equivalents and intermittently at a maximum rate of 671 MW equivalents.

The foregoing describes several preferred embodiments of the invention. Variations will be obvious to a person of ordinary skill in the art and it should be realized that the inventors perceive their invention encompassing all within the purview of the following claims:

CLAIMS

1. A process for the generation of electrical power from coal which comprises:

(a) forming a raw low BTU gas by gasifying said coal;

(b) passing said raw gas into a purification zone wherein sulfur compounds are removed to produce a purified low BTU gas;

(c) passing a first portion of said purified low BTU gas to a combustion zone and combusting said gas and generating electrical power from said combusted gas;

(d) passing a second portion of said purified low BTU gas to a reaction zone;

(e) forming methanol in said reaction zone;

(f) passing said methanol to a storage vessel; and,

(g) generating additional electrical power from said methanol by combusting a portion thereof in said combustion zone.

2. The process defined in Claim 1 wherein the first portion of low BTU gas is not sufficient to generate electrical power at the maximum rate attainable as if a sufficient amount of low BTU gas was passed to said combustion zone.

3. The process defined in Claim 1 wherein the products of said combustion from said combustion zone are passed to a gas turbine to generate electrical power.

4. A process for the generation of electrical power substantially as described herein with reference to any of Figures 4 to 8 of the accompanying drawings.

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